INCREASING THE COMPETITIVENESS OF E-VEHICLES IN EUROPE

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ABSTRACT

The 2011 EU White Paper on Transport sets ambitious goals for phasing out conventionally fuelled cars in cities. Take-up and expansion of electric vehicles (e-vehicles, or electromobility) are one way to achieve this, as proposed by, i.a., the European Green Cars Initiative, the EU Action Plan on Urban Mobility, European alternative fuels strategy, and so on.

This paper discusses incentives for the take-up and use of e-vehicles that are in place in different European countries. Especially, it analyses Norway and Austria, in order to establish and understand factors influencing the competitiveness of e-vehicles and potential market penetration. Norway currently enjoys the world's largest take-up of electric cars per capita, achieved through a package of incentives, which includes reductions in the cost differences between conventional vehicles and e-vehicles, preferential treatment with respect to parking, road charging exceptions, access to bus lanes, and a strategy for charging stations supported by the government. Austria, on the other hand, has used the concept of Model Regions with government support to stimulate market introduction. So far, this has been a less effective approach.

The analysis includes socio-economic factors as well as convenience and time savings. It describes a system dynamics model framework and how it can be established and calibrated to replicate real e-vehicle markets and used to show how different elements of a government strategy will contribute to the uptake of e-vehicles.

The loss of different tax revenues on fossil fuels, caused by market uptake of non-fossil fuels, is a central concern to several European governments. The fiscal effects are non-trivial –especially in the longer run. In times of constrained public budgets, the cost of lifting new technologies into the market is strenuous and increased expenditure and/or drop in tax revenues must be recouped. We point to the importance of a strategy for the phasing out of policies.

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1 BACKGROUND AND INTRODUCTION

The 2011 EU White Paper on Transport sets ambitious goals for phasing out conventionally fuelled cars in cities. Take-up and expansion of electric vehicles (e-vehicles, or electromobility) are one way to achieve this, as proposed by, i.a., the European Green Cars Initiative, the EU Action Plan on Urban Mobility, and the European alternative fuels strategy. Although several countries have set sales and stock targets for electrification as part of their climate policy, the number of such vehicles in use is very limited in most countries. A report from the Electric Vehicles Initiative (2013) shows that their 15 members have an EV-stock of 0.02 percent while the target is 2 percent. This discrepancy is part of the background for ERA-net's Electromobility+ programme, which funds 20 European projects on this topic. One of these is the project, "Competitive Electric Town Transport" (COMPETT), which is the source for this paper.

In this paper, the term electric vehicle (EV) is used and understood as battery electric vehicles (BEV) that are only powered by electricity, including Extended Range Electric vehicles (EREV). Hybrid Electrical Vehicles (HEV) and Plug in Hybrid vehicle (PHEV) are not pure EVs.

The recent years have seen substantial developments in the EV markets globally. The price of EVs has gone significantly down in real prices (figure 1). At the same time, the new models are better equipped and enjoy better warranties and dealer coverage. Further, a large variation of vehicles is now available. In 2009, the only alternative to the Think in Norway were plain 4 wheel MCs or older second hand imported French EVs. Despite this, and as opposed to most other countries, Norway managed to keep a small EV market going throughout the early 2000s.

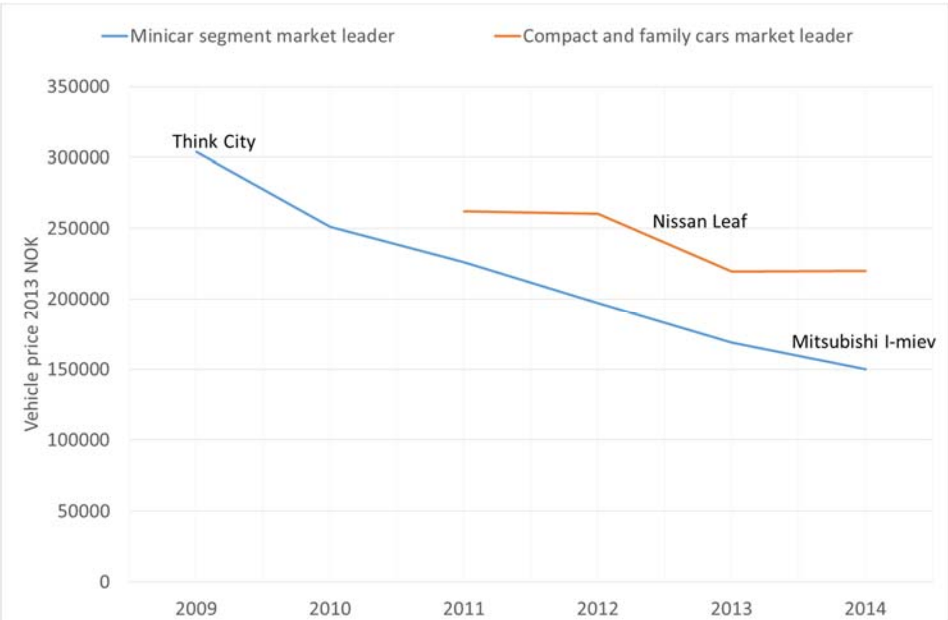


Figure 1: Typical price development of EVs in the Norwegian market. Net costs, fixed 2013 prices. (NOK 1 = €0.12 at time of writing)

2 EUROPEAN INCENTIVES AND MARKET SHARES

The market for EVs has increased between 2010 and 2014 in most countries, but most profoundly in Norway, which currently is the European leader in EV adoption both in absolute numbers and in market share (table 1 and figure 2). The market share of sales in the first half of 2014 was close to 13 percent in Norway, with the Netherlands and Estonia as the next countries, relatively far behind with market shares around 1 percent. During the last year, the Norwegian EV market growth has been greatest in smaller cities and rural areas, and not in the pioneer areas of electromobility, i.e. the larger cities and their vicinities.

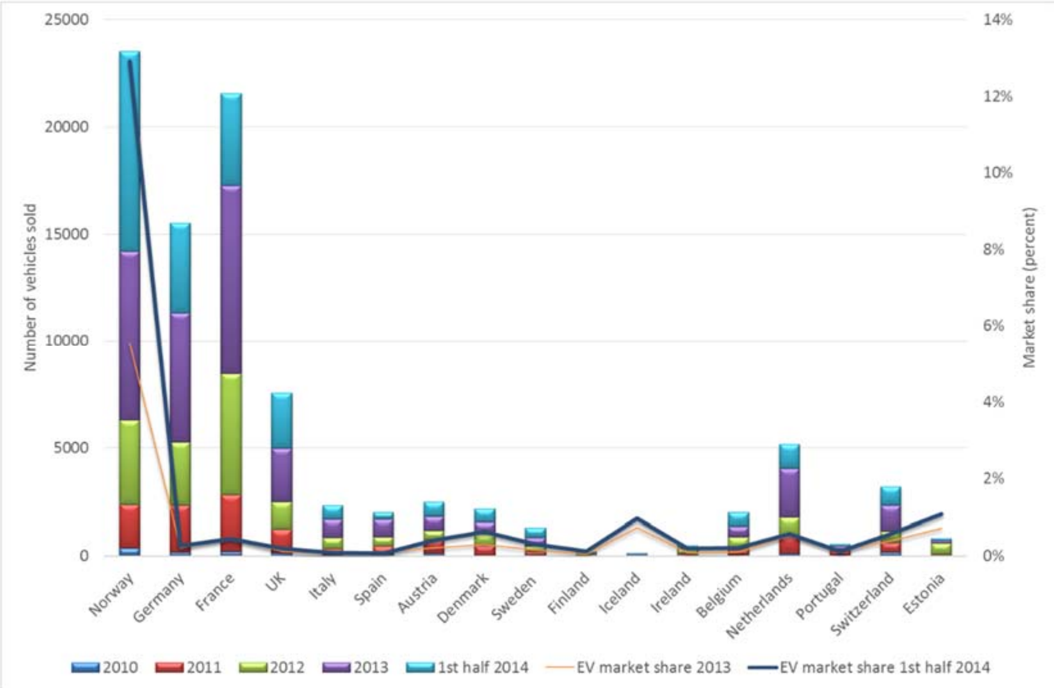


Figure 2: 2010-2013 BEV total sales and share of total market sales in different countries. Sources: ACEA, local statistical services, internet fora, and industry monitors.

Table 1 also presents the various EV incentives that are in place in the selected countries. The table is an approximation and a snapshot only, because several subsidies come and go, are only in place in certain regions or cities, are limited in time and value, and so on. The most widely used incentives in this selection of European countries are registration tax exemption, annual vehicle tax exemption and purchase subsidy/grant. In some countries, these are rebates rather than exemptions. It is worth noting that the highest market shares, especially in Norway and Iceland, are associated with non-financial incentives as well, like free street parking. This observation is supported by the findings of Moch and Yang (2014) who compare incentives and market share in different countries and show that there are limits to what can be obtained by fiscal incentives alone.

Norway, in particular, stands out with a high market share and a wide array of incentives. These are presented and discussed in more detail later in this paper.

Table 1: EV market shares and incentives in a selection of countries. Sources: European Union (2013), Wikipedia (2014), Shahan (2014) and ACEA (2014)[7]

Country	EV market share 2013	Purchase grant/ subsidy	Registration tax excemptio	Annual tax excemption	Free street parking	Free toll roads	Bus lane access	VAT excemption	Other incentives
Norway	6,1		x	x	x	x	x	x	
Netherlands	5,55		x	x	(x)				
Iceland	0,94				x			x	
France	0,83	x							x
Estonia	0,73		x						x
Sweden	0,71	x	x	x					x
Switzerland	0,44		x	x					
Denmark	0,29		x		(x)				
Austria	0,26		x	x					
Germany	0,23			x					
Portugal	0,21	x	x	x					
Spain	0,18	x							
Belgium	0,17		x	(x)					x
Finland	0,17		x						
United Kingdom	0,17	x				London CC			
Italy	0,11			x					
Ireland	0,08	x							
Czech Republic	N/A			x					
Greece	N/A		x	x					x
Latvia	N/A		x						
Luxembourg	N/A	x							
Hungary	N/A		x	x					
Romania	N/A	x	x						

3 MARKET POTENTIAL

This section draws extensively on Hjorthol (2013) and Hjorthol et al. (2014, forthcoming).

EV uptake and growth potential in the markets depend, firstly on the early adopters and future diffusion into the rest of the market and, secondly, on the proportion of daily trips and trip chains that possibly can be made within EVs' limited range and battery charging needs.

Different actors and decision makers will react differently to new products. It is therefore essential that there is someone who is willing to try out new things. Rogers (1995) distinguishes between five groups of users of innovations with different socio-economic and personal characteristics and communication behaviours: *Early users (Innovators*); *Early adopters*; *The early majority; The late majority; and Laggards*. Using new environmental technology can often have rebound effects and involve costs for the users. Environmental innovations cannot usually develop into a large market without parallel public incentives (Figenbaum et al., 2014).

Studies of early adopters of EVs indicate common socio-demographic characteristics across countries. The early adopters are relatively young, a majority are men, they have high education and income, and belong to households with more than one car (Econ analyse, 2006; Rødset 2009; Transport for London 2010; Pierre et al. 2011; Campell et al. 2012; Hagman et al. 2011; Ozaki and Sevastyanova 2011). The majority also lives in, or in the vicinity, of larger cities. Figenbaum et al., (2014) evaluate the Norwegian

[7] For some countries, these sources are in conflict. The table may have errors.

market and find that the largest potential for further expansion lies in the early majority, which considers buying an EV next time or haven't made up their minds, and the late majority, who still don't consider the EV option. Their suggested positioning of the groups suggests a continuing positive diffusion process in Norway.

Range anxiety (the fear of being stranded due to a depleted battery) is ubiquitous but the range of new EVs and larger batteries keeps increasing. For the purpose of analysing EV potential, we apply a range limit of 80 km in winter (October- March) and 120 km during summer (April-September).

The *Norwegian* travel survey 2009 (NTS 2009) shows that the population made on average 3.3 trips per day. The average trip is 12.0 km and lasts for 24 minutes, and the average length travelled per day per person is 42.1 km. A large proportion of daily trips are short. Only 27 per cent are 10 km or longer. Of car driving distances made as driver, only 5.3 percent are longer than 50 kilometres. Relate this to the critical range of an EV, only 2.7 percent of the car trips are longer than 80 km (winter limit), and 1.4 percent are longer than 120 km (summer limit). *In Austria*, the average trip in 1995 was 9.5 km and lasted for 23 minutes, and the average length travelled per day per person was 29 km. In Lower Austria the average length is 43 km in 2008. Trips are short also here: Six (Lower Austria 2003) and two (Vorarlberg 2008) percent of trips exceed 50 km. (Hjorthol et al., 2013; 2014)

Studying the total distance as a car driver on an average day in NTS, Hjorthol et al. (2014) find that among all drivers as many as 88 percent have no need for recharging on an average day.

However, trips need to be analysed in connection, in *trip chains*. The single trips are not isolated entities. They day add up, and while a trip itself may be short, it could be part of a longer trip chain, with a possible need of recharging. Looking at Norwegian car trips, only 8 percent of the chains are longer than 80 km and only 4 percent of the are longer than 120 km. In total, there are 43 days per year which exceed the range limits in Norway. On these days, it is necessary to recharge in order to use an EV. Recharging can be done during the day if the stops are long enough and the conditions are suitable with access to at least an ordinary electric socket for normal charging (typically home or work). Of the relatively few car drivers in Norway who exceed the range limit per day, between 24 percent and 29 percent stop at home between 1-5 hours during the day, sufficient for some charging. In addition, about 10 percent can park at a designated parking area, and have a *potential* for recharging there. Looking at stops that exceed 5 hours, we find that between 20 and 40 percent have this long stop at work, and therefore a good potential for recharging.

On total for Norway, four percent of the trips, six percent of the trip chains and 12 percent of the days during a year exceed the range limit. In a year and on average, the EV range (without recharging) is exceeded 43 days. On these days, 24-29 percent have a stop at home of between 1-5 hours, and between 20 and 40 percent have stops at work of more than 5 hours, which give possibilities for (full or partly) recharging.

4 SERAPIS – A SYSTEM DYNAMICS MODEL FRAMEWORK

SERAPIS (Simulating the Emergence of Relevant Alternative Propulsion technologies in the car and motorcycle fleet Including energy Supply) is a dynamic car fleet and propulsion technology model. SERAPIS utilises the methods and principles of System Dynamics. The model SERAPIS is programmed with the System Dynamics software Vensim® (www.vensim.com). The development of SERAPIS started in 2009 (Pfaffenbichler, Emmerling et al. 2009). Later on SERAPIS was adapted for and used in several other projects (Renner, Baumann et al. 2010; Frey, Mayerthaler et al. 2011; Pfaffenbichler, Castro et al. 2012). Basically SERAPIS models

- the development of the fleet of motorised individual vehicles (cars, 2-wheelers),
- the share of alternative propulsion technologies (internal combustion engine, hybrid and battery electric) and
- the utilities needed to provide ultra low carbon electric energy for the consumption of the emerging e-vehicle fleet.

The development of the total car fleet can either be modelled internally employing a linear elasticity model or be defined as an external scenario. The choice of propulsion technology is modelled utilising a multinominal LOGIT model. The utility of each propulsion technology is a function of investment costs, operating costs, variety of makes and models on the market, density of service stations and range with a single tank contents or battery loading. The development of the vehicle fleet by propulsion technology is modelled in on year time steps from the base year 2010 up to the end year 2050. A comprehensive description of the first version of SERAPIS is given in (Pfaffenbichler, Krutak et al. 2011). The requirements of the project COMPETT necessitated a significant revamp of SERAPIS. First of all the propulsion technologies taken into account have been defined more clearly:

- ICE: internal combustion engine incl. non-plug in hybrids (e.g. the normal Prius)
- PHEV: plug in hybrids and range extender vehicles (e.g. Prius Plug In, Volt)
- BEV: battery electric vehicles

Furthermore the car fleet has been subdivided into first and second+ cars and the following three car categories are taken into account:

- Compact (everything from micro-cars up to cars like Renault Clio, Volkswagen Polo etc.)
- Family (everything from Volkswagen Golf, Ford Focus, etc. up to BMW 3, Mercedes C, etc.)
- Luxury (BMW 5 and 7, Audi A6, A7 and A8, Mercedes E and S, Ferrari, Lamborghini, BMW X series, Jeep Wrangler, etc.)

In the first version of SERAPIS utility/generalised costs from range and density of service stations have been treated independently. In reality there is a trade-off between them, i.e. if range is higher the importance of the density of service stations declines and vice versa. This fact is taken into account in the new version of SERAPIS. Furthermore, utility/generalised costs from time savings due to exemptions for electric vehicles (use of bus lanes, dedicated parking, etc.) have been included.

Data input for the model SERAPIS is handled using Microsoft Excel® files. As a dynamic model, SERAPIS needs two different types of input data. First, a set of input data for the base year is needed. This includes a large number of data items about the vehicle stock, costs, taxes, fuel, annual mileage, car ownership levels, discount rate, parking, charging availability and costs, road charging, range, EV benefits, etc.

The second type of data are time series data to define scenarios. Some of the data are defined as a yearly rate of change while others are defined in absolute values. The latter is necessary for values which are zero in the base year. Scenario definition data include many of the same data items as described for base year data, above.

A set of parameters from the calculation of the utilities for the multinominal LOGIT model can be used to calibrate the model. Nevertheless, it has to be mentioned that the market share of electric vehicles in Austria is still too low to carry out a formal calibration similar to that of four stage transport models. *Figure* 3 shows a comparison of the number of battery electric vehicles from 2003 to 2013 as reported from the Austrian registration statistics and as calculated by SERAPIS. As the market share of battery electric vehicles in Norway already exceeded 5 percent in 2013 and in first half of 2014 reached close to 13%, a formal calibration is the next step of this work.

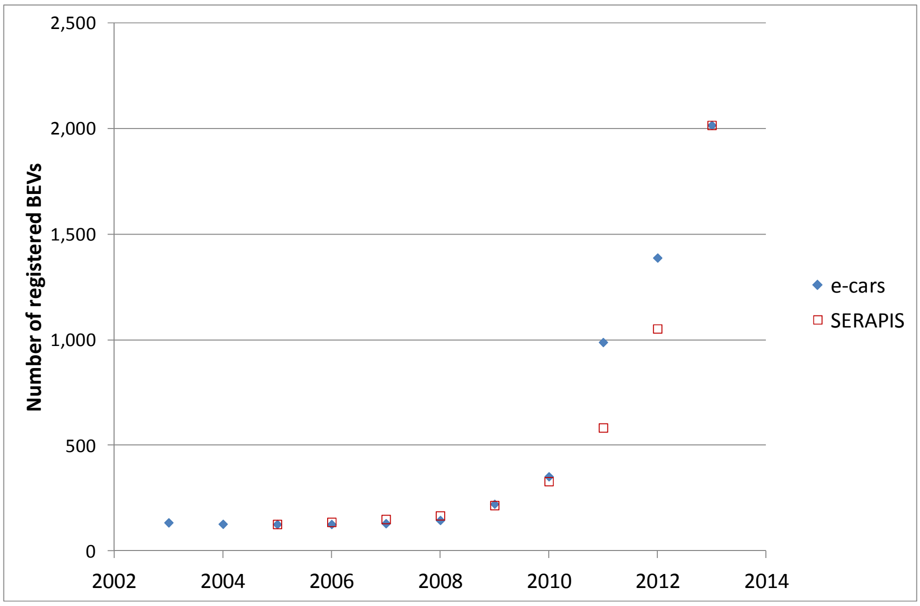


Figure 3: Comparison of the SERAPIS results with the Austrian registration statistics 2003-1013

The main output of SERAPIS are time series data about the number of vehicles by first and second+ car, vehicle type and propulsion technology for each year. From this basis, SERAPIS can calculate different environmental and economic indicators for the evaluation of scenarios within the framework of a cost benefit or multi criteria analysis, or cost effectiveness.

5 MORE ABOUT NORWAY AND AUSTRIA

5.1 Norway

Norway has, as stated above, the largest number of EVs per capita. This is the result of a long-term consistent strategy made by the Norwegian government. Back in the late eighties, early nineties, there have been promotional activities for EV's in Norway. Thanks to early activists, the Norwegian government decided to abolish (at first temporary, later permanently) import taxes for EV's. Later, VAT was exempted and a complete set of incentives has been put in place. The Norwegian company Th!nk was a producer of electric cars (Hoogma, Kemp et.al. 2002) since the early nineties, long before a large selection of makes and models became available. Production of the Th!nk City ceased in 2011. These developments in incentives, together with key developments on the supply side and in market penetration are combined in figure 4.

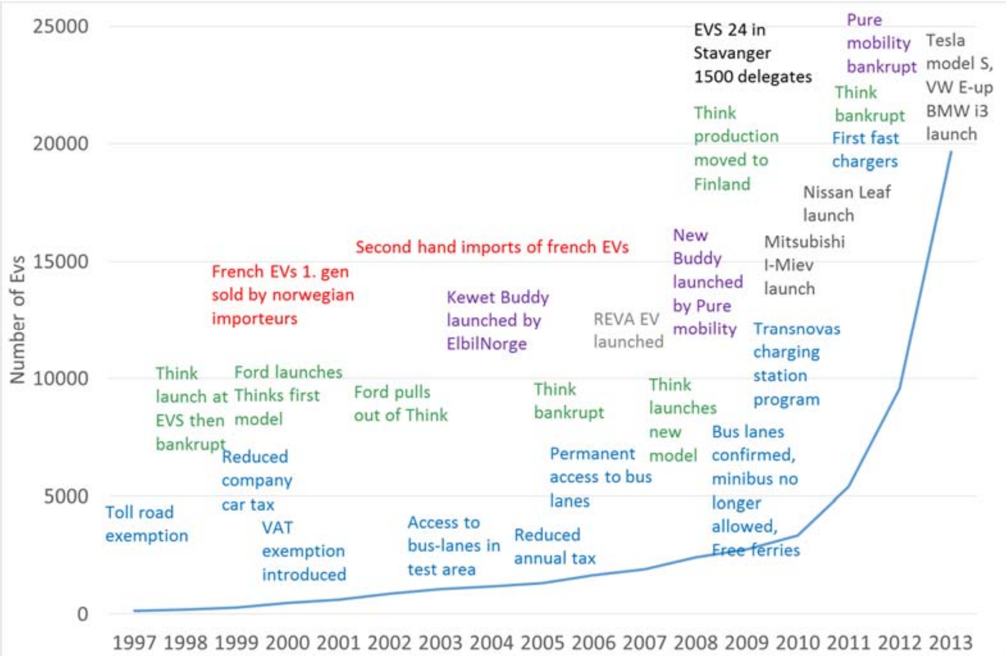


Figure 4: Developments in the market and in EV policies in Norway 1997-2013

When looking at the different Norwegian EV incentives, Figenbaum et al. (2014) used a division into three different types of incentives: (1) fiscal, 2) direct, and 3) incentives giving relative advantages to compensate for drawbacks. This again is based on Figenbaum and Kolbenstvedt (2013). Parts of this elaboration is reproduced in table 2.

Table 2: Figenbaum et al. (2014)'s evaluation of EV Norwegian incentives

Incentives	Introduced	Importance for uptake
Fiscal incentives - reduce purchase price/yearly cost gives competitive price		
Exemption from registration tax	1990/1996	+
VAT exemption	2001	++
Reduced annual vehicle license fee	1996/2004	+
Reduced taxable benefit on company cars	2000	0
Direct subsidies to users – reducing usage costs and range challenges		
Free toll roads	1997	++
Reduced rates on ferries	2009	0
Financial support for charging stations	2009	+
Fast charge stations	2011	+
Reduction of time costs and giving relative advantages		
Access to bus lanes	2003/2005	++
Free parking	1999	+

++ crucial factor in explaining the EV market development,
+ less important factor or only important in some market niches
0 factor that up to 2013 was not considered important

Norway is in many ways unique. It is wealthy, distances are long, it is mountainous, and winters are cold. While the former might promote EV usage, the latter three limit their application. Expansion outside of the major urban areas and commuting distances necessitates a suitable charging infrastructure. This is under (rapid) development led by both a nationally-funded organisation (Transnova) and local and private initiatives. At the time of writing, there are about 5000 charging outlets (nobil.no) across Norway, of which about a hundred are fast charge stations. This means that a cross-country drive is a possibility for most EVs.

A survey among 1 721 EV owners in Norway shows that they value the economy of electric motoring, the environmental benefits, and most importantly; that EVs meet their transport needs (Figenbaum, Kolbenstvedt and Elvebakk 2014). They do not report large problems with having an EV and have developed various strategies before and during their travel for coping with possible range challenges. They plan better, borrow a car, use the family's second car and they drive more economically, turn of AC and heater or use a fast charger. Seven percent of respondents with several cars in the household and 20 percent in single-EV households report that trips are not made.

Norwegian EV owners suffer relatively little from range anxiety and are comfortable using on average 80-85 percent of the battery's range. 65 percent charge their vehicle daily, 20 percent charge 3-5 days per week and another 15 percent charge 1-2 times per week at home in a garage, carport or outdoor. Public normal charging is used at least monthly by about half the EV owners, and 7-14 percent use it weekly. Workplace charging is more widely used than public charging. The average annual number of fast charges per vehicle is about 14. 27 percent use fast chargers more than once per month, and 6 percent are weekly users. EV-only owners use fast charging more than owners in multicar households. Normal charging is usually free. Half of the respondents do not pay for fast charging.

Almost all EV owners (87 percent) will continue to buy EVs in the future. The motivations to buy again are related to economy and incentives, environment, and the joys of EV motoring (comfort, low noise), and that it fits their needs. Some owners also state that it is the technology itself, believing it to be the future of motoring, that is important.

The COMPETT project has compared attitudes to EVs among EV owners and average car owners (2 241 members from the Norwegian Automobile Association (NAF) were interviewed). Figure 5 illustrates that those with experience of EVs have a rather different attitude to EVs than an average car owner. The latter group finds more disadvantages and few advantages with EVs. Therefore, it seems important to distribute knowledge of EVs in order to increase the market share. The study also shows that both media and social networking is of large importance in the diffusion process. Among the members of the NAF who own ordinary cars, 30 percent would consider an EV the next time they buy a car. Among those *who have friends with EVs*, the rate is much higher: 44 percent.

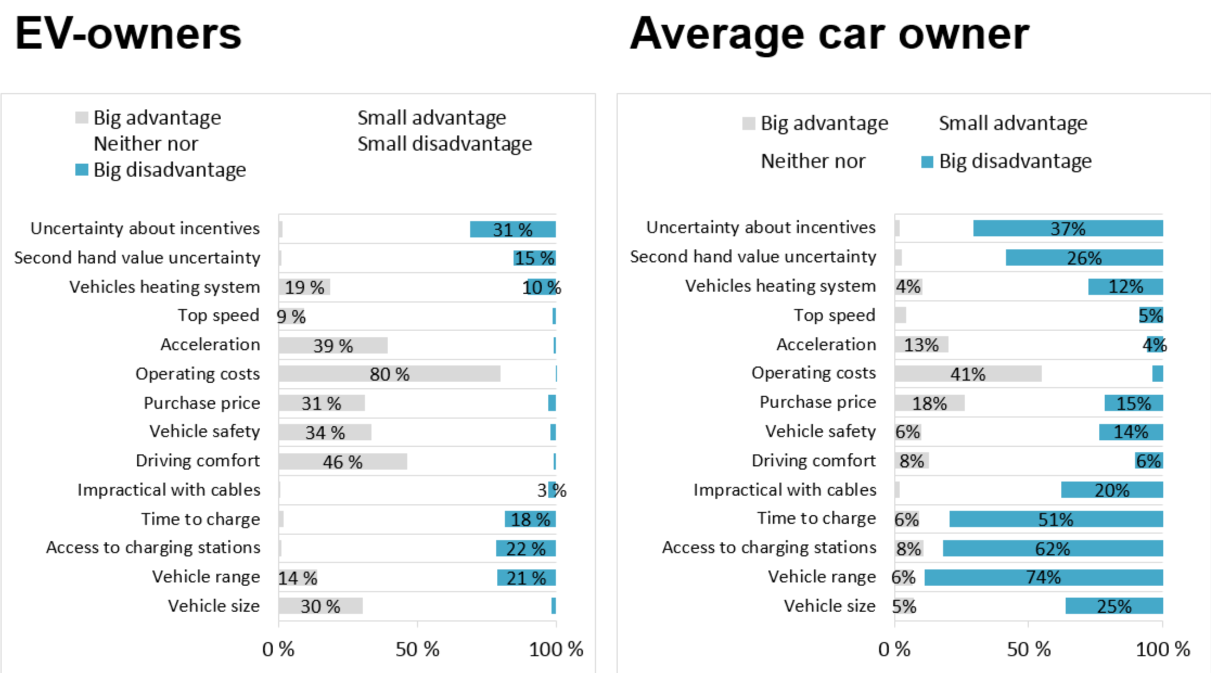


Figure 5: EV owners and average motorists evaluate EVs different

The Norwegian EV policy, with its many incentives, long history and the establishment of Transnova, a government body giving financial support to the establishment of public charging facilities, have reduced the barriers for E-mobility. Norwegians were ready to buy EVs when the big automakers launched their models around 2011 (Figenbaum and Kolbenstvedt, 2013).

The Norwegian incentives are highly valued by the EV owners, and represent crucial motives for buying this type of cars. Figure 6 shows that lower operating costs is by far the most important factor for EV owners when buying a new vehicle, much more so than for the NAF members. Lower energy cost per km is an essential part of this, but also free toll-roads and free parking could be part of this parameter. EV owners also place a higher significance on competitive price than NAF members do. In addition, reduced annual circulation tax is important for EV owners.

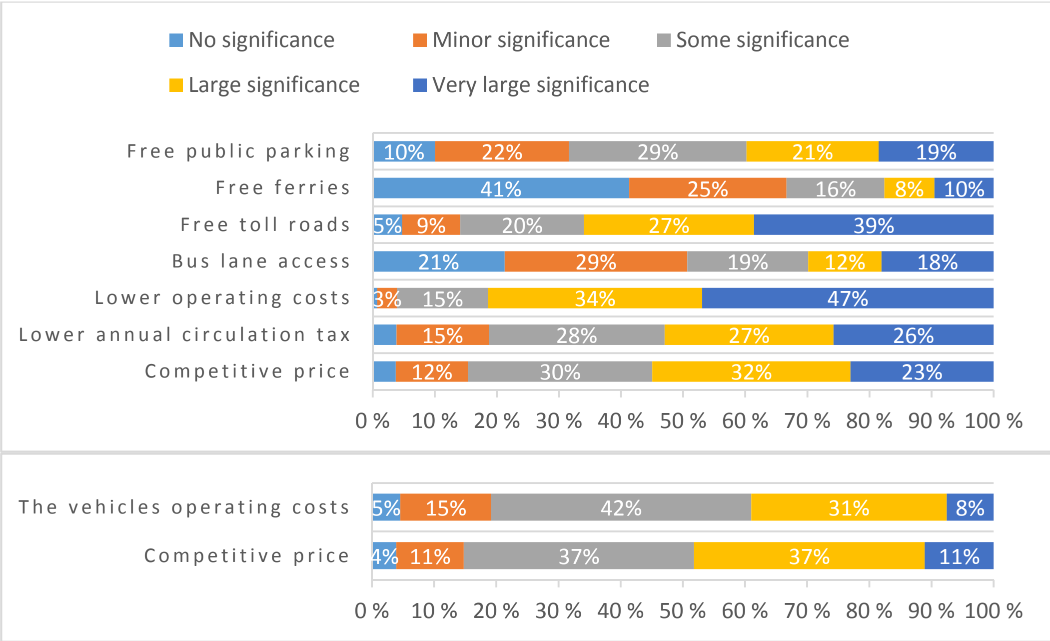


Figure 6: Degree of importance of factors and incentives related to buying a new vehicles. On top as seen by EV owners in Norway (n = 1 721). Below by average car owners in the Oslo-Kongsberg region (n = 2 241). Percent

There are large regional differences in the reported advantages from the various incentives. Bus lane is emphasised in the Oslo-region, where time savings are large (up to 30 minutes). Reduced ferry rates are more important in the coastal regions. EV owners seem to live and work in areas where they can use these facilities to a larger extent than the average car owner. However, the EV market is spreading into smaller towns and even in areas where no local incentives are at work. This fact suggests that incentives are not the only factor influencing the EV-buyer's choice.

In figure 7, each of the 400+ Norwegian local municipalities is recoded with EV market penetration (EVs per capita) and a calculation of the value of local EV incentives. Section 6 provides more details about this calculation. Some municipalities enjoy zero or hardly any incentives (no bus lanes or toll roads, parking is already free, etc.). In others, the local value can be substantial, due, e.g., to large travel time savings from bus lane access, toll road exemptions and ferry rebates. The outliers with very high market penetration are wealthy areas with especially high benefit from access to bus lanes, or small islands with costly connections to the mainland. In the other end of the spectrum, the outliers with relatively low market shares despite high value of incentives are rural areas where access to the nearest city (Trondheim) is costly. Assumingly, EVs cannot compensate for the troublesome distances and ferry crossing there. The linear trend line has a fairly good level of fit only from this bivariate relationship, which suggests that EV market shares depend strongly on local incentives. (Purchase incentives are not included in the figure.)

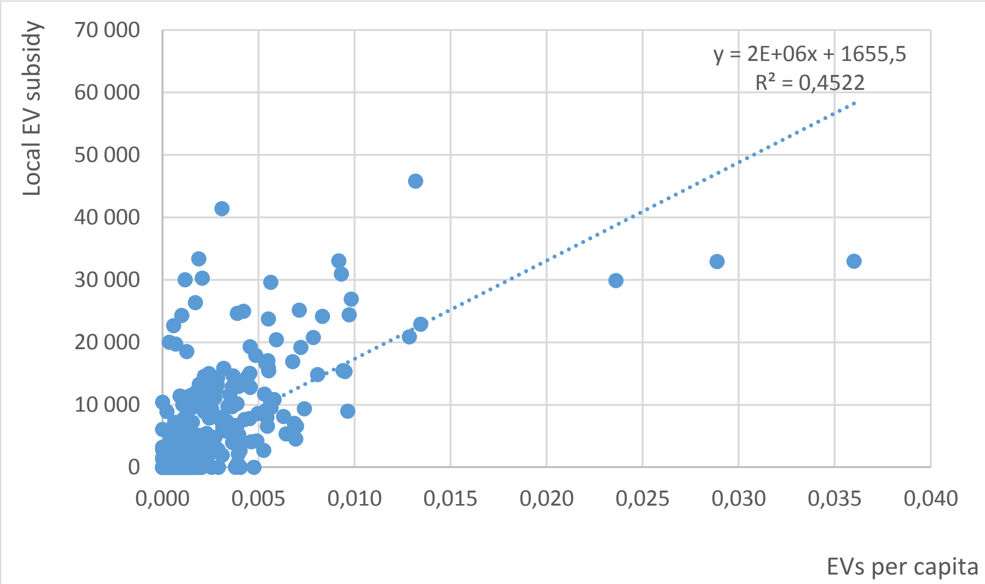


Figure 7: EVs per capita in Norwegian municipalities, compared with the annual value (NOK) of local EV benefits. (NOK 1 = EUR 0.12 at time of writing)

5.2 Austria

The number of e-vehicles in the yearly stock is rising rapidly (see figure 8), but of course not comparable with other countries like Norway with interesting benefits and VAT exemption.

The share of E-vehicles compared to the total stock (4,7 million cars) is around 0.06 percent by now.

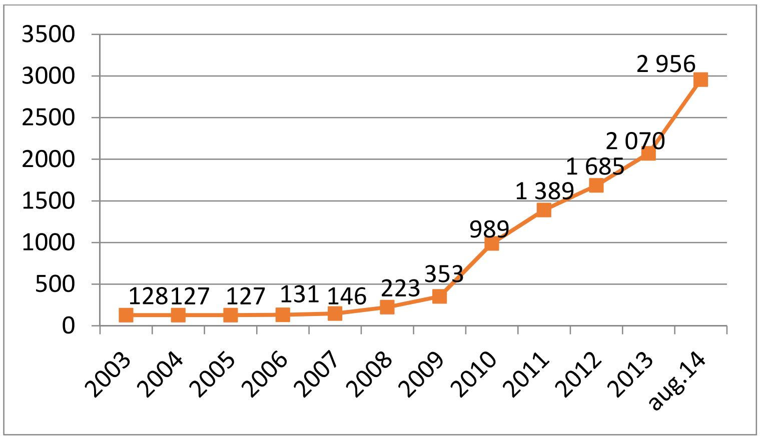


Figure 8: EV development in Austria.

5.2.1 Incentives for e-mobility

Electric vehicles are exempted from the purchase tax and the annual motor vehicle tax, resulting in about 4,000 EUR savings over five years. Financial incentives for private users are only given from the nine Austrian federal states: the subsidy schemes differ a lot but can offer grants up to 4,000 EUR per e-vehicle. Also insurance companies offer discounts from 10 to 20 percent for e-vehicles on their monthly rates. Some cities offer free parking for e-vehicles (not Vienna).

Financial incentives and purchase tax credits for companies and communities are offered within the national climate change programme “klima:aktiv”.

The rates are staggered according to the type of vehicle introduced, the level of CO_2 reduction achieved and the amount of renewable energy used for new cars with alternative propulsion systems: e.g. a tax credit of 500 EUR for hybrid vehicles.

Up to 4,000 EUR are granted for purchasing EVs, if powered with renewable energy, otherwise only 2,000 EUR. Since 2013 also PHEVs and REEVs are eligible within the new funding regime and get subsidies from 500 – 3,000 EUR, depending on the level of CO_2 reduction and amount of renewable energy used. Pedelecs are granted with 200 resp. 400 EUR (when powered with green electricity), E-scooters get subsidies from 250 – 500 EUR.

Within “klima:aktiv” 1.100 e-mobility projects with 7300 e-vehicles (primarily e-bikes/e-scooters and light-weight community e-vehicles) were supported, as well as the setting-up of 700 charging stations. Overall support volume of €6,3 m triggered €41,4 m of investments and generated and secured 320 new „green jobs“. Reduction of CO_2 emissions of 8.800 tonnes/a.

5.2.2 Pilot regions for E-mobility

Within the Austrian Climate and Energy Fund the introduction of e-mobility is promoted by R&D projects and the pilot regions for e-mobility. These regions focus on electric vehicles powered by renewable energy sources and the integration of “vehicle use schemes” in combination with the public transport system. Users within the pilot regions pay a monthly “mobility rate” which includes not only the electric vehicle, but also the use of public transport.

To date, seven pilot regions have been established reaching about 3.5 million people or 40 percent of the population of Austria. These model regions are the major drivers for the establishment of charging infrastructure in Austria:

(1) in 2009 the Vorarlberg/Rhine valley region (VLOTTE Project) with 360 e-cars/LDVs and 120 charging stations; mobility services contracts including leasing of e-cars, railway/public transport pass, car sharing and free charging; provision of $20m^2$ photovoltaic power for each e-car;

(2) in 2010 the Greater Salzburg Area with 100 e-cars and 750 e-bikes; ElectroDrive „e-mobility with the public transport pass“: leasing/purchasing concept for e-bikes, e-scooters, Segways and e-cars; free charging with „green electricity“ (photovoltaic; hydro-power);

(3) the urban agglomeration of Graz: e-mobility Graz; goal 500 e-cars, 1200 e-bikes, 140 public charging points; e-mobility services packages for large fleet operators (vehicles, public transport, charging stations);

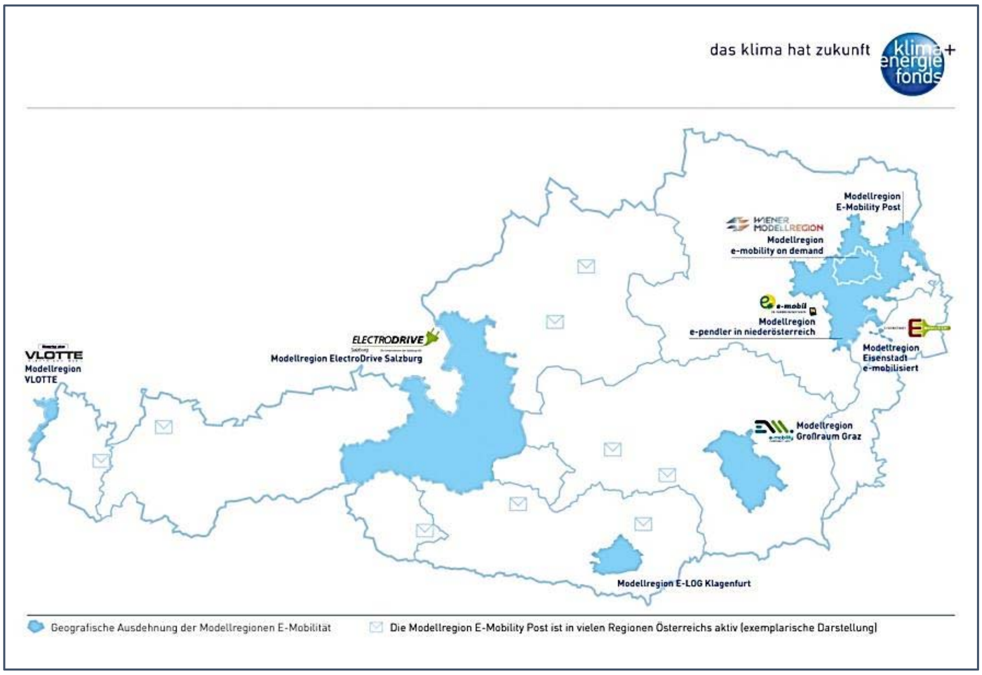
(4) Vienna metropolitan area; e-mobility on demand; goal of 500 cars, 100 charging points; multi-modal mobility and public transport pass with focus on commuters and fleet operators; renewable energy for 2000 e-cars;

(5) e-mobility in Lower Austria: 49 municipalities, use of electric vehicles by commuters, promising last mile solutions;

(6) The Austrian Post e-mobility delivery services in Vienna metropolitan and 12 regional distribution centres: 200 electric utility vehicles for postal mail delivery

(7) e-log in the City of Klagenfurt; promising e-logistics solutions with 200 electric vehicles (goal) with focus on SMEs.

As a next step, particular attention will be given to linking the different pilot regions by facilitating interoperability of electric vehicles and charging stations. For all the pilot regions particular attention is given to further integration of e-mobility and public transport, the facilitation of multi-modal solutions and interlinking the different pilot regions to facilitate interoperability of electric vehicles and the charging infrastructure.



So far, due to users and testers in pilot regions, the lessons learned can be pointed out as follows:

- 120-150 km range of e-vehicles is sufficient for daily journeys (50 percent of car trips <5km); combined mobility services provide solutions for long distance.
- Environmental advantages of e-vehicles are important
- Preferential charging with green electricity from 100 percent renewable energy sources (photovoltaic, wind and water power, biomass)
- 80 to 90 percent of slow charging at home/office with ordinary power plugs (2,3 kW power). Re-charging of batteries is only needed every third day!
- Public charging stations are psychologically important (limited e-vehicle range), but little used, except for fast, high power (55kW) charging stations.
- Higher purchase prices of e-cars require some financial support at present.

6 COST OF INCENTIVES AND OPTIMAL PHASEOUT

Subsidy cost and revenue loss to local and central governments can amount to substantial budgetary stress. Successful EV policies may also cause other, consequences like reduced fuel tax revenues, congested bus lanes, reduced parking availability, reduced walking and cycling, etc. Some governments have therefore capped their incentives already at the launch of the incentive – either up until a fixed future date, until a certain level of goal achievement is reached, or until an earmarked budget is depleted. The Norwegian government declared in 2012 that their generous package of benefits will stay in place till year 2018 or till 50,000 BEVs are registered, whichever comes first (Norway is forecast to reach 50,000 BEVs already in 2015). However, when the incentives where introduced, c.f. table 2, no conditions for termination was specified.

For Norway, Fridstrøm and Alfsen (ed. 2014) have estimated that EV incentives represent lost revenues from purchase tax, annual tax, VAT exemption and toll road exemption lie in the region of NOK1,5-2 bn (EUR 0.18-0.25 bn). The VAT exemption alone costs M€41.3 annually (Figenbaum and Kolbenstvedt, 2013). The total picture includes also costs of local incentives, lost fuel taxes, increased electricity taxes, etc.

A life cycle calculation shows that Norwegian EV incentives cost €10.500 per saved ton of CO_2, while the going price on the European CO_2 permit market is about €5 per ton (Holtsmark and Skonhoft, 2014). Their study has been contested among other things for using unrealistic annual mileage assumptions for EVs and car ownership and unrealistic usage patterns for local incentives, and for solely focusing on the short term cost of CO_2-mitigation, ignoring the long term effects of getting the market cycle of cost reductions and technology improvements on the way. Fridstrøm and Alfsen (2014) show that the Norwegian EV fiscal incentives in fact have positive net welfare effect for society. Additionally, electricity in Norway is mostly hydropower. Using this for transport is a CO_2 neutral solution, opposed to other situations, where the place of CO_2 generation is only changed. In any event, to move transport energy use from private consumption (gasoline) to the CO_2 permit market (electricity) will be contribute to GHG reductions (Fridstrøm and Alfsen, 2014).

As part of the COMPETT project, Norwegian EV owners have been asked to identify the various local user benefits they enjoy when using their EVs. From this, we have calculated the annual average economic value of the incentives for the average EV driver. In table 3, the results have been scaled up to the size of the EV fleet in April 2014, 25 000 vehicles. The economic value is 16 000 NOK (€1,900) per vehicle and 400 million NOK (€48m) for the total fleet per year. This rests on the following assumptions:

- Based on the National valuation of time study, the value of time saved in queue due to the access to bus lanes is NOK 280 per hour.
- The value of the toll-road exemption is estimated by combining respondents' information about usage of toll-road, and the cost of the toll-road that they could be using, given maximum available rebates. This approach is associated with some uncertainties. The average reflects the fact that not all EV owners pass toll roads. The regional differences are very large.
- The value of free parking is calculated as a weighted average of EV owners' stated weekly saving. This total figure corresponds well with findings of a forthcoming study of this incentive (Fearnley, 2014)
- The reduced ferry price is a very crude estimate

Table 3: Calculated average values per year of different local incentives per car and for total fleet in Norway Total fleet in Norway = 25 000 EV's in April 2014. Euros/year

Incentive	Value per car Euros/year	Value for EV fleet million Euros/year
Bus lane	940	24
Toll-road	434	11
Free parking	398	10
Free ferries	145	4
Total	1 928	48

There are large regional differences in the advantages the users report from the various incentives. The bus lane is more valued in the Oslo-region, where time savings are large (up to 30 minutes), whereas reduced ferry rates are sometimes extremely valuable in some coastal regions in the west and mid parts of Norway. The share of EV owners using both free toll road and access to bus lane more than twice a week when driving to work is only 33 percent. In addition, 26 percent uses toll roads only and 6% bus lanes only. It appears that EV owners live and work in areas where they can enjoy these facilities.

Bus lane access will be a benefit to society as long as spare capacity is used without delaying buses. The toll-road incentive leads to lower income for the toll-road company. This company has a loan that was used to build roads. When income is reduced, either the rate per paying vehicle must be increased, or the period of payment is prolonged. Free ferries are different from free toll-roads. The ferry cost should cover the marginal cost of transporting the vehicle and persons in the vehicle. If fewer pay, the rate per paying vehicle is increased or the subsidy from the province or government must increase. Free parking means that municipal income per parking space is reduced, that fewer parking spaces are available to other paying users, and reduced circulation. The cost of the free parking incentive for municipalities may thus exceed the value of the incentive for the EV owner.

6.1 Cost-effective phase-out

The introduction of a new technology and departure from ICEs require large subsidies and investments and political commitment. However, the goal is to establish a self-sustaining market which can thrive in the future without public support. The question is how to deal with increasing cost of promoting electromobility due to the larger uptake, and not harm the current high usage of EV's. Figure 8 gives a schematic illustration of the principle. Here, we only look at EV incentives and not off-setting tax increases in alternative markets. In the early years, the industry suffers from poor and expensive technology, users face uncertainties with respect to second-hand value, range, safety, etc., and the vast majority is largely unaware of the EV alternative to ICEs. As the size of these problems falls, the relative disadvantage EVs falls and it becomes wasteful to maintain costly or relatively inefficient incentives. Which incentives should be abolished first? Forthcoming SERAPIS modelling will address this by identifying the least cost-effective and most detrimental policies. Table 2, above, already hints to the various incentives' effectiveness, but do not consider cost-effectiveness.

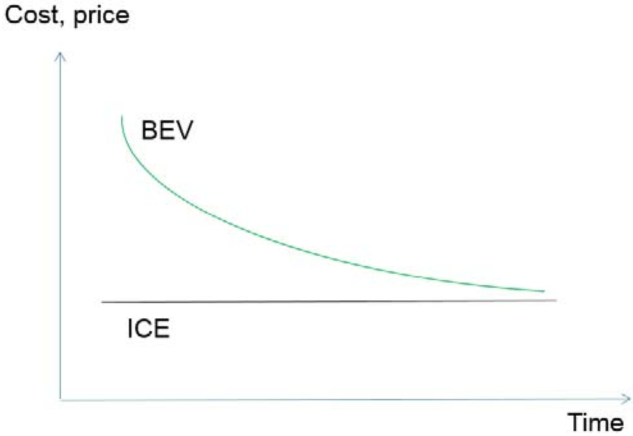


Figure 8: As EV disadvantages fall, less incentives are needed in order to make EVs competitive.

7 CONCLUSIONS, POLICY RECOMMENDATIONS AND DISCUSSION

The main conclusion of this paper is that successful market uptake and expansion of electric vehicles is the result of massive, expensive and combined policies. The high market penetration in Norway has been achieved through a broad package of incentives, which include reductions in the cost differences between conventional vehicles and e-vehicles, preferential treatment with respect to parking, road charging exceptions, access to bus lanes, a strategy for charging stations which is accompanied by generous government support, and technological advances. In tandem with this, the Norwegian growth is the result of diffusion mechanisms such as increasing awareness of the technology and products. With the continuation of current incentives and a well-communicated plan for gradual changes, the market share of EVs will probably continue to increase. The fact that these policies have state backing and apply to all parts of the country has probably reduced the perceived risk for market players like car importers. The policies are clear and predictable.

The differentiated use of incentives and our EV user surveys point to an important aspect of the Norwegian success. Since the users have different needs, national and local stakeholders and the industry must use a broad package of incentives in marketing this new technology. In addition to addressing differing local barriers to EV use, the package of incentives sums to a forceful and reinforcing combination of stimulus to the market.

For countries which are still in an early phases, this paper has shown that the potential for EV uptake is promising. EVs are already a real option for the majority of peoples' everyday trips and trip chains. However, the EVs' relative disadvantages to the ordinary car must be reduced, and the lack of knowledge in most populations must be addressed. We have demonstrated the importance of information in the process of dissemination of new technology. People with family or acquaintances who own an EV are much more likely to consider an EV themselves. Technological diffusion is a process which takes place in a social system where communication is a crucial element. Key elements in this communication process are, 1) how the new technology is perceived with respect to relative advantages and compatibility with user needs and societal norms; and 2) observability and visibility, ie opportunity to experience the products. The first groups to be targeted are the early users

(Innovators) and the early adopters. They are: urban dwellers, relatively young, mostly men, with high education and income, and belong to multicar households.

Finally, it is worth highlighting the importance of cost-effective policies. Most EV incentives have a high cost. Inefficient policies should be avoided, including those which are harmful to other parts of society, like, e.g., bus lane access which could severely delay buses if not implemented properly. Cost-effective policies should be the first to be introduced, and the last to be withdrawn.

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